STUDIES ON NUTRIENT ABSORPTION OF RICE PLANTS IN TAIWAN (PART 4)

Comparative Study on Rice Nutrition in the First and Second Crops in Some Paddy Fields

by

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Our study intends to throw light on the status of nutrient absorption of rice plants in sub-tropical region, such as in Taiwan, from the nutrio-physiological point of view. Previous investigations[1,2,3] on this subject had been undertaken with glass-house experiments and special emphasis was laid on the effect of temperature on nutrient absorption and growth of rice.

It is commonly acknowledged in Taiwan that the yield of the first crop of rice exceeds that of the second crop. It is suspected that the mode of nutrient uptake between the two crop seasons might be different. This study has been carried out to investigate the actual status of plant growth and nutrient uptake in some paddy fields with a purpose to elucidate the special features of rice nutrition in the two crops.

METHOD OF EXPERIMENT

1. Year, localities and varieties investigated:

Two localities in 1959 and three localities in 1961 cultivated with Japonica varieties were investigated.

Table 1. Cercumstance of paddy field investigated

Year	Locality and soil	Crop season	Variety
1959	Yuanlin, Slate alluvial soil	1st	Chianun 242
		2nd	Chianun 242
	Taipei, Sandstone & shael alluvial soil	1st	Taichung 65
		2nd	Taichung 65
1961	Yuanlin, Slate alluvial soil	1st	Chianun 242
		2nd	Chianun 242
	Taoyuan, latosol	1st	*No. 155
		2nd	Chianan 2
	Shanchung, Sandstone & shale alluvial soil	1st	Taichung 65
		2nd	Taichung 65

* Note: Indistinct Japonica variety known as No. 155 by farmeres.

2. Sampling method:

Rice plants grown in paddy fields with local traditional cultivation and fer-

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tilization were sampled five or six times untill harvesting for measuring agronomic characters of plants and chemical analysis.

In 1959 a randomized block design was used for sampling. Plants growing in a plot with a size of 1/1000 ha. were sampled in four replications at a time. Plants were sampled six times during the growing period. For this purpose, six plots were arranged at random in four blocks. Chemical analysis was made in duplication.

In 1961, 30 bushes of plants were sampled at random from each of the fields at one time. The sampling was made five times untill harvesting. Chemical analysis was replicated three times.

3. Chemical analysis:

The contents of N, P, K in the plants were determined with all samples. With the plants taken at harvesting in 1961, the contents of Ca, Mg, Si, Fe, Mn were analyzed in addition to those of N, P, K. The method of chemical analysis is as same as that used in the previous paper.[3]

RESULTS

The results of investigation of Yuanlin and Taipei paddy fields conducted in 1959 are shown in Table 2, 3 and Fig. 1, 2, 3.

The N, P, K contents in rice straw increased rapidly after transplanting as

Table 2. Measurements at maturity (1959)

Locality		Yuanlin		Taipei	
Season / Variety		1st crop Chianun 242	2nd crop Chianun 242	1st crop Taichung 65	2nd crop Taichung 65
Growth doy		111 (25/II–15/VI)	107 (29/VII–12/XI)	114 (19/III–11/VII)	116 (13/VIII–7/XII)
Plant length (cm)		109	92	93	97
Tiller number		15.5	12.9	16.2	11.2
Grain yield (Kg/ha)		5,462	2,033	3,355	2,178
Straw yield (Kg/ha)		5,184	3,177	3,316	4,254
Grain/straw ratio		(105/100)	(64/100)	(101/100)	(51/100)
Grain	N%	1.18	1.26	1.28	1.42
	P_2O_5%	0.592	0.592	0.657	0.779
	K_2O%	0.32	0.38	0.37	0.48
Straw	N%	0.77	0.88	0.89	1.07
	P_0O_5%	0.167	0.246	0.329	0.335
	K_2O%	1.96	1.97	1.94	1.33
Nutrients absorbed (Kg/ha)	N%	104.3	53.7	72.5	76.6
	P_2O_5%	41.0	19.9	33.0	31.2
	K_2O%	118.9	70.5	76.8	67.2

Note: Nutrient contents are presented as per cent on oven-dry basis.

Table 3. Distribution of three elements absorbed in plants (1959)

Locality	crop	Nutrients absorbed / Part	N Kg/ha	N (Index)	P_2O_5 Kg/ha	P_2O_5 (Indox)	K_2O Kg/ha	K_2O (Index)
Yuanlin	1st	Grain	64.5	(62)	32.3	(79)	17.5	(15)
		Stem	12.7	(12)	3.5	(8)	62.4	(53)
		Leaf	27.1	(26)	5.2	(13)	39.0	(33)
		Total	104.3	(100)	41.0	(100)	118.9	(100)
	2nd	Grain	25.6	(48)	12.0	(61)	7.8	(11)
		Stem	5.3	(10)	1.9	(9)	26.5	(38)
		Leaf	22.8	(42)	6.0	(30)	36.2	(51)
		Total	53.7	(100)	19.9	(100)	70.5	(100)
Taipei	1st	Grain	42.9	(59)	22.0	(67)	12.4	(16)
		Stem	7.3	(10)	4.5	(13)	35.8	(47)
		Leaf	22.3	(51)	6.5	(20)	28.6	(37)
		Total	72.5	(100)	33.0	(100)	76.8	(100)
	2nd	Grain	30.9	(40)	17.0	(55)	10.5	(16)
		Stem	9.3	(12)	5.1	(16)	32.4	(48)
		Leaf	36.4	(48)	9.1	(29)	24.3	(36)
		Total	76.6	(100)	31.2	(100)	67.2	(100)

Note: Plant samples were divided into three parts, i. e. grain, stem, and leaf and sheath.

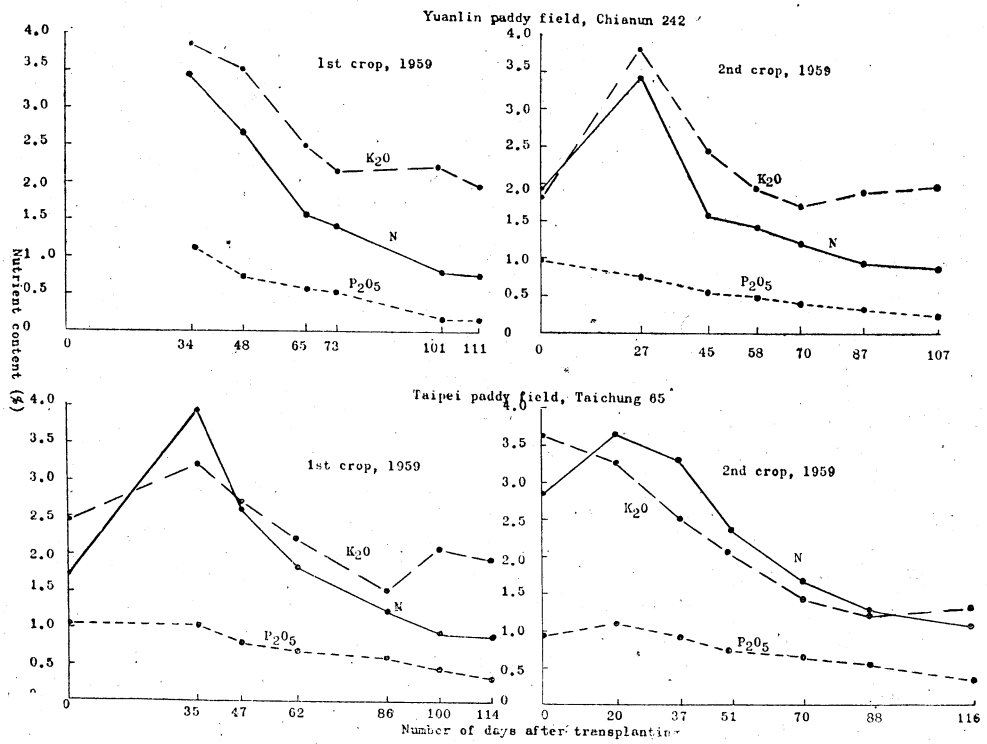

Fig. 1. Change of nutrient contents in rice straw at successive growing stages (1956)

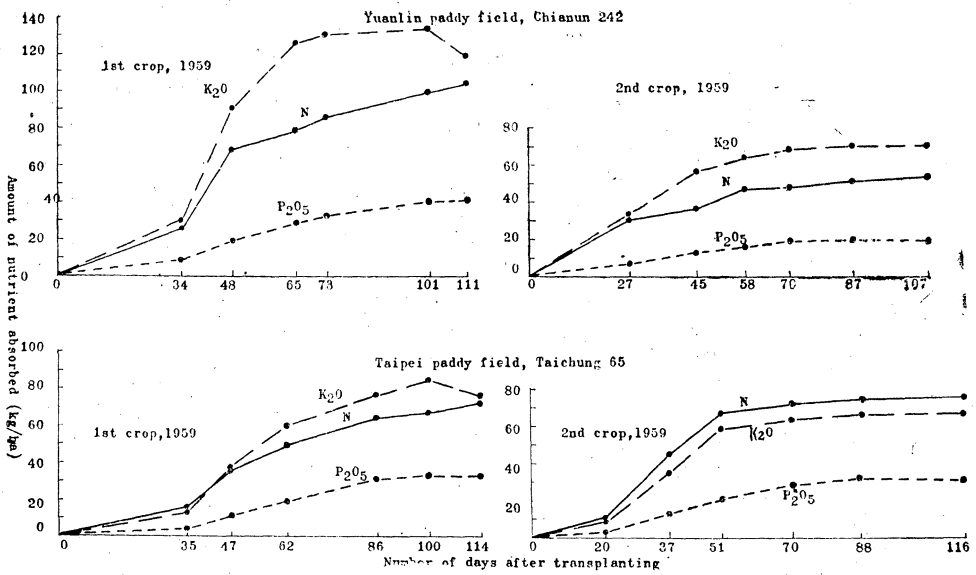

Fig. 2. Amounts of untrients absorbed by plants at successive growing stages (1959)

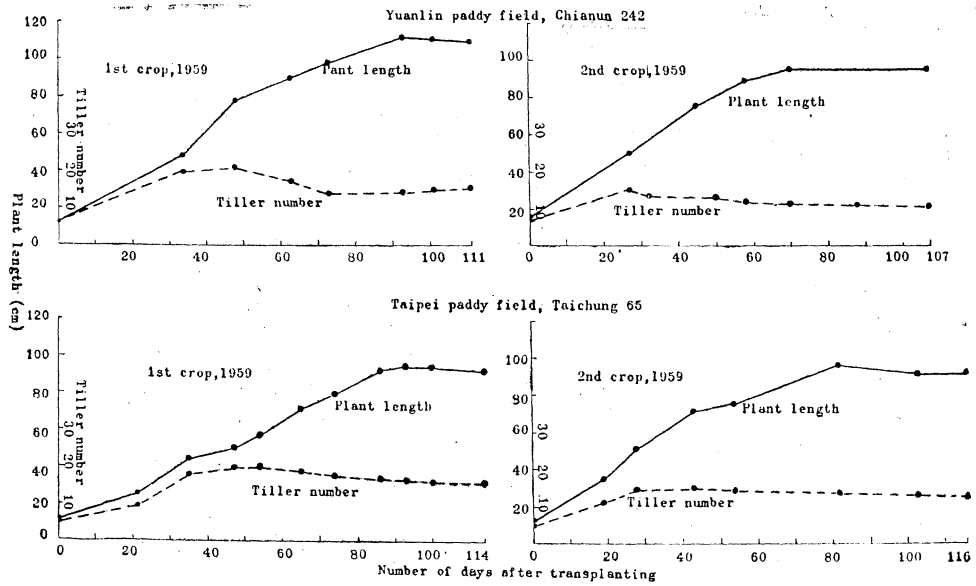

Fig. 3. Plant length and tiller number at successive growing stages (1959)

shown in Fig. 1. The maximum concentration appeared at about 35 days after transplanting in the first crop and 20 days in the second crop, then the concentration made a slow dropping untill harvesting with the lowest at the time of harvesting, excepting the K contents increased again at the later growing stage with the minimum within 20 to 30 days before harvesting. This fact may be explained as following. N and P or other organic constituents such as carbonhydrate accumulat in straw, which are translocated to ear at ripening period, while K is still remained and concentrat in straw, resulting in increase of K concentration in

straw after heading. As seen in Table 3, grain contained only 11–16% of total K absorbed, while it contained 40–62% and 55–79% of total N and P, respectively.

As shown in Fig. 2, the plants absorbed a large quantities of N, P, K during the period from 30 to 90 days after transplanting in the first crop and from 20 to 60 days in the second crop. In the first crop, they tend to continue absorbing the nutrients at the latter growing stage but not in the second crop owing to dropping of temperature. Among three elements, K was absorbed the most in amount with the exception of the second crop in Taipei field in which the largest amount of N absorption was found. An extremely low yield and nutrient absorption of rice in the second crop as compared with the first crop at Yuanlin field was caused by the famous August 7th flood in 1959 which devastated the area.

More tiller number, higher yield and wider grain/straw ratio were generally observed in the first crop than these of the second crop regardless of locality.

The results of investigation at three localities conducted in 1961 are shown in Table 4, 5, 6 and Fig. 4, 5, 6. The trend of the yields in the two crops or the nutrient contents in straw at successive growing stages are similar to that observed in 1959. The highest nutrient contents were found at the time of transplanting in some localities. In this case, fertilizer dressed on the nursery bed might resulted in high concentration of nutrients in seedlings. At the ripening stage, the curve of K contents rised while the curves of N and P contents were reclining untill harvesting as given in Fig. 4.

Table 4. Measurements at maturity (1961)

Locality		Yuanlin		Taoyuan		Shanchung	
Season / Variety		1st crop Chianun 242	2nd crop Chianun 242	1st crop No. 155	2nd crop Chianun 2	1st crop Taichung 65	2nd crop Taichung 65
Growth day		108 (28/II–14/VI)	105 (27/VII–9/XI)	106 (26/III–10/VII)	105 (1/VIII–14/XI)	112 (28/III–18/VII)	104 (3/VIII–25/XI)
Plant length (cm)		108	116	96	108	97	104
Tiller number		16.7	14.0	14.8	16.7	20.8	21.7
Grain yiold (Kg/ha)		6,093	4,910	3,538	3,636	4,034	3,813
Straw yield (Kg/ha)		4,712	4,736	3,444	4,423	4,869	4,663
Grain/straw ratio		(129/100)	(104/100)	(103/100)	(82/100)	(83/100)	(82/100)
Nutrients absorbed (Kg/ha)	N%	97.3	96.3	63.8	81.8	84.0	99.2
	P_2O_5%	46.0	33.8	38.1	35.9	44.8	36.6
	K_2O%	110.9	108.3	82.8	106.7	117.6	95.5
	CaO%	15.5	18.6	11.4	16.0	16.3	13.5
	MgO%	25.8	27.3	14.3	22.5	21.3	25.4
	SiO_2%	658.1	598.4	423.3	465.9	693.6	589.1
	Fe%	0.6	1.0	0.6	0.7	1.1	1.2
	Mn%	2.7	4.0	0.5	4.0	1.9	2.8

Table 5. Nutrient contents of plants at maturity (1961)

Locality		Yuanlin		Taoyuan		Shanchung	
Season		1st crop	2nd crop	1st crop	2nd crop	1st crop	2nd crop
Grain	N%	1.12	1.20	1.09	1.13	1.12	1.38
	P_2O_5%	0.658	0.541	0.808	0.627	0.695	0.645
	K_5O%	0.33	0.29	0.36	0.44	0.38	0.31
	CaO%	0.05	0.05	0.05	0.05	0.06	0.06
	MgO%	0.17	0.16	0.20	0.18	0.16	0.19
	SiO_2%	3.04	2.88	3.57	2.79	3.99	2.78
	Fe%	0.0023	0.0058	0.0032	0.0029	0.0053	0.0045
	Mn%	0.0055	0.0081	0.0022	0.0112	0.0068	0.0075
Straw	N%	0.61	0.79	0.73	0.92	0.80	1.00
	P_2O_5%	0.126	0.153	0.275	0.297	0.344	0.257
	K_2O%	1.93	1.98	2.03	2.05	2.10	1.79
	CaO%	0.26	0.34	0.28	0.32	0.24	0.24
	MgO%	0.33	0.41	0.21	0.36	0.30	0.39
	SiO_2%	10.00	9.65	8.62	8.24	10.93	10.36
	Fe%	0.0096	0.0154	0.0148	0.0125	0.0173	0.0231
	Mn%	0.0501	0.0761	0.0108	0.0823	0.0344	0.0539

Note: Nutrient contents are presented as per cent oven-dry basis.

Table 6. Rate of nutrient translocation from straw to grain (1961)

Locality	crop	N	P_2O_5	K_0O	CaO	MgO	SiO_2	Fe	Mn
Yuanlin	1st	70	87	18	20	40	28	24	12
	2nd	61	79	13	13	29	24	28	10
Taoyuan	1st	60	75	15	15	49	30	18	12
	2nd	50	58	15	11	29	22	16	10
Shanchung	1st	54	63	13	15	30	23	20	14
	2nd	53	67	12	17	28	18	14	10
Average	1st	62	75	15	17	40	27	21	13
	2nd	55	68	14	14	29	21	19	10

Note: Rate of nutrient translocation $= \frac{\text{Nutrient in grain}}{\text{Total nutrient absorbed}} \times 100$

The N and P absorption increased with plants grew, but at harvesting only the K absorption curve dropped in many cases as shown in Fig. 5 or Fig. 2. In this connection, it is considered that K can be easily released from plant tissue by water especially when leaf become yellowing or drying at ripening stage. Consequently, under-estimation of total amount of K absorbed at harvesting may occure if rainfall in fields or washing of plant samples in the laboratory are responsible for dissolution of K out of plant tissue.

According to Table 5 and 6, the nutrient contents in straw was in the following

order, Si>K>N>Mg÷Ca>P>Mn>Fe, and that in grain was as follows, Si>N>P>K>Mg>Ca>Mn>Fe. N and P in straw which are regarded as readily mobilized in plants were translocated to ear in a large quantities at ripening period. The rate of nutrient translocation from straw to grain was in the following order, P>N>Mg>Si>Fe>Ca>K>Mn.

A comparison between the two crops, with respect to growth and nutritional status of plants based on average of five trials, i.e. two localities in 1959 and three localities in 1961 with two crops at each locality, is given in Table 7 and Fig. 7. 8.

Plants grown in the second crop showed vigorous growth with taller culm length and more nutrient absorption at the vegetative stage but poor growth and less nutrient absorption at the reproductive stage. In general, it resulted in less

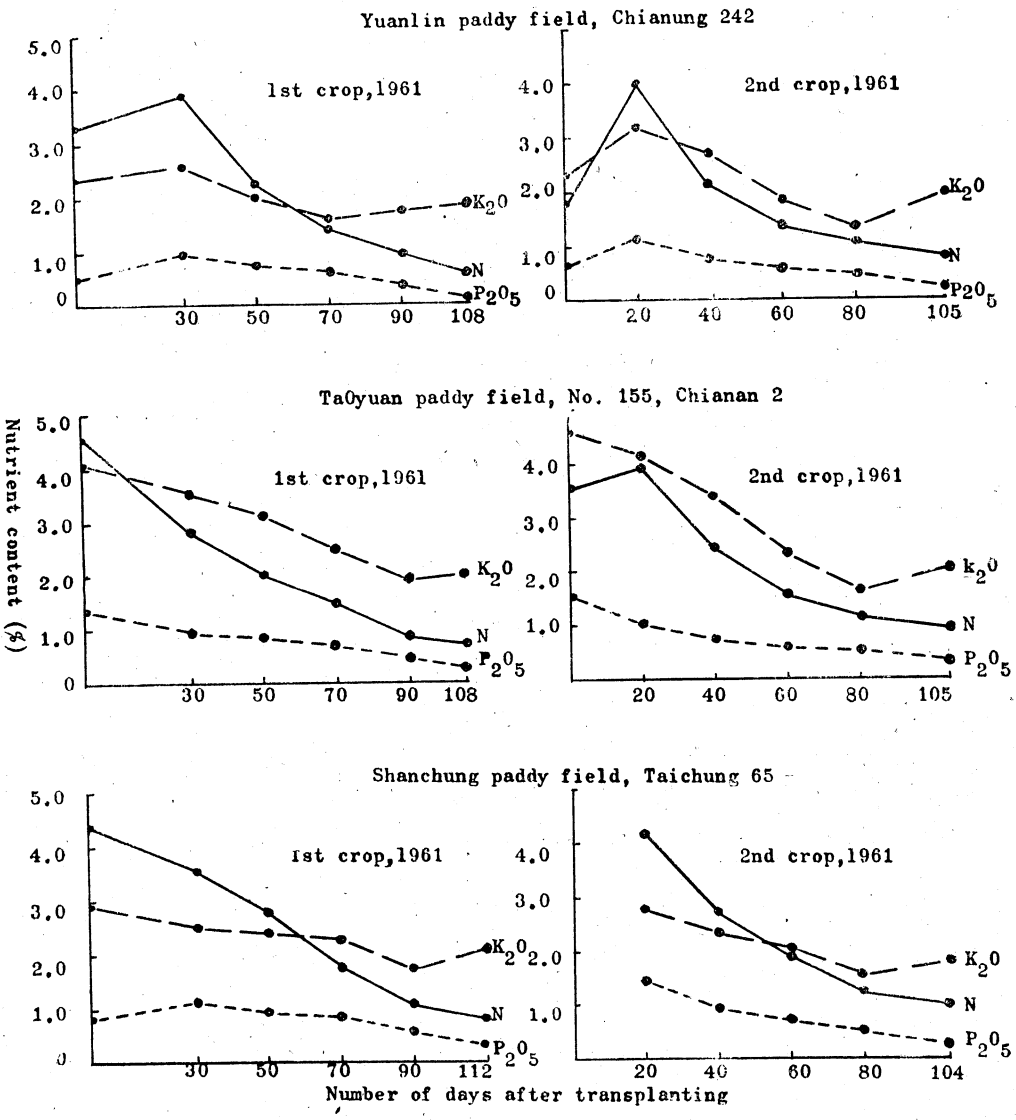

Fig. 4. Change of nutrient contents in rice straw at successive growing stages (1961)

tiller number, lower grain yield and grain/straw ratio in the second crop.

Although there was little difference in total amount of N absorption between the two crops, the N contents in straw of the first crop was lower than that of the second crop at maturity due to higher rate of N translocation from straw to grain in the first crop.

The K contents in straw and amount of K absorbed at ripening stage in the second crop were significantly lower than that of the first crop. However, it is still obscure whether this different K status between the two crops plays a significant grain production.

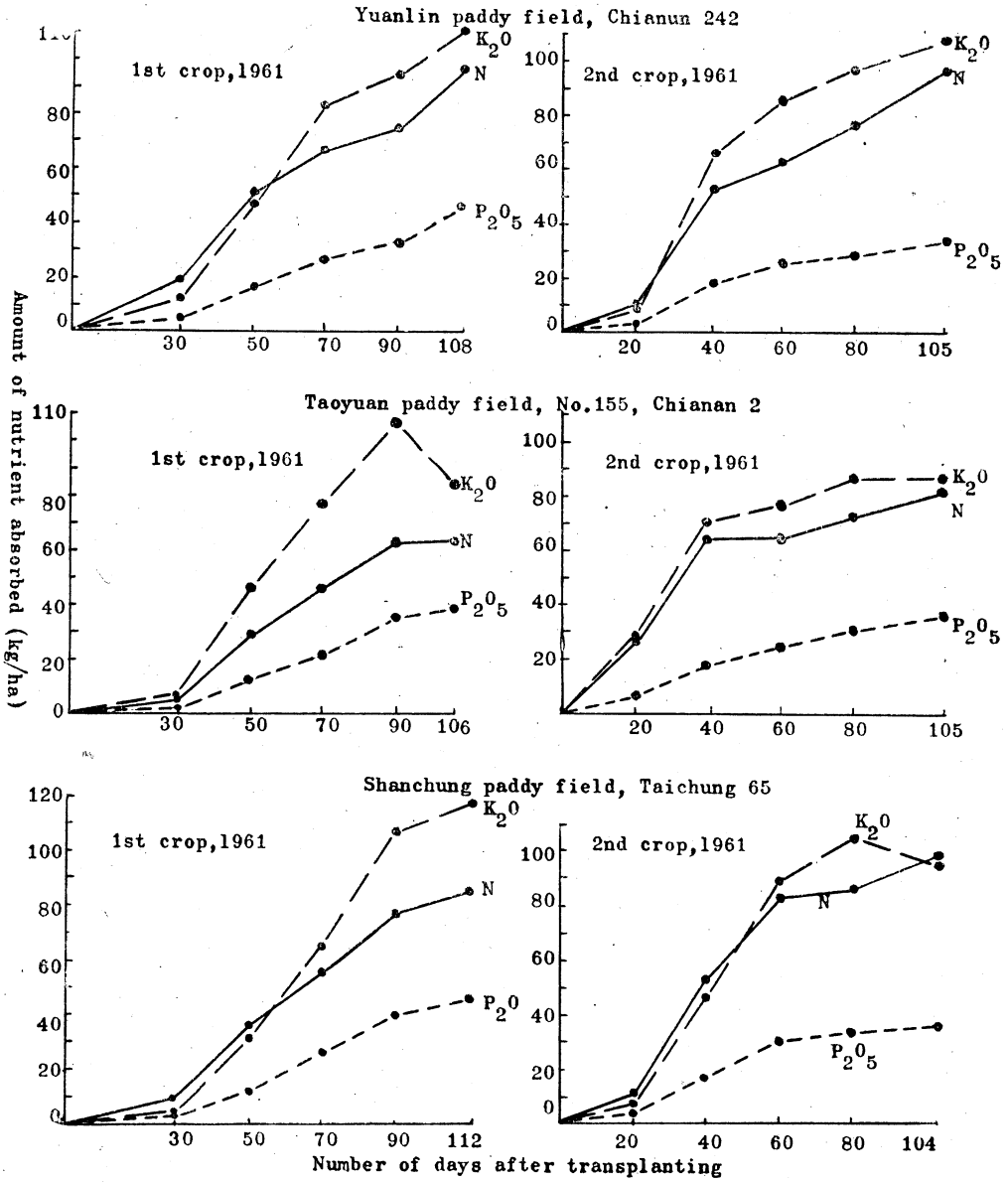

Fig. 5. Amounts of nutrients absorbed by plants at successive growing stages (1961)

It is well known that rice grows with rising temperatures in the first crop, while with declinins temperatures in the second crop as seen in Fig. 8, showing the average temperatures recorded every day in 1959 at the Agricultural Farm of TARI. It may be assumed that these different modes of temperature change or daylight hours influence the soil properties, rice nutrition and its physiological growth as well. It is especially true that low temperatures at mature period of the second crop slow down the ripening of plants and also retarded the normal development of grains, resulting in the loss of yield.

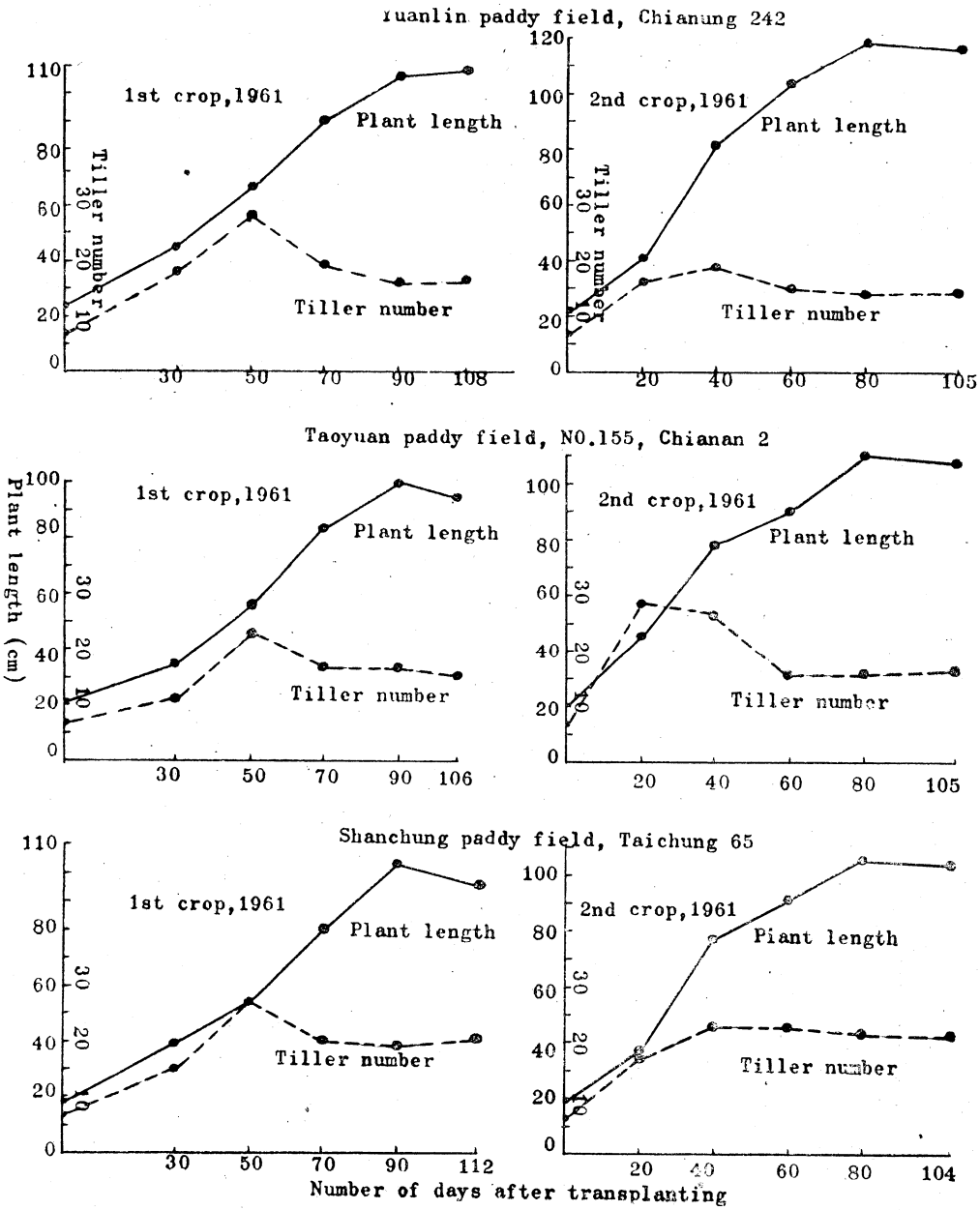

Fig. 6. Plant length and tiller number at successive growing stages (1961)

Table 7. Comparison of growth and nutritional status of plants between two crops

Growoth habit	1st crop	2nd crop	Nutritional Status		1st crop	2nd crop
Grwoth day	110	107	Grain	N%	1.16	1.28
Plant length (cm)	100	103		P_2O_5%	0.68	0.64
Tiller number	16.8	15.3		K_2O%	0.35	0.38
Grain yield (Kg/ha)	4,496	3,322	Straw	N%	0.75	0.91
Straw yield (Kg/ha)	4,305	4,251		P_2O_5%	0.24	0.25
Grain/straw ratio	104/100	78/100		K_2O%	1.99	1.82
Rate of nutrient translocation to grain N%	63	50	Total absorbed (Kg/ha)	N%	84.0	81.0
P_2O_5%	74	64		P_2O_5%	40.6	31.5
K_2O%	15	14		K_2O%	101.3	89.5

Note: The figure on the table is average of five trials.

DISCUSSION

The average amounts of fertilizer three elements removed from the soil by the aerial part of plants in one crop season are as follows; N–P_2O_5–K_2O, 82–36–95 Kg/ha. Taking N as 100, the indexes of the three elements absorbed were calculated as follows; N:P_2O_5:K_2O, 100:44:116. K absorption was 16% higher than N. The importance of N is well recognized by Taiwan farmers and the amounts applied to the soils almost reach the level actualy needed for maximun yleld[4]. Concerning P and K, the amounts used by farmers as fertilizers are far less than that removed by the plants especially for K. Considerable amounts of P and K from soil itself or K from irrigation water may cover principal natural supply of nutrients. Nevertheless, it is easy to see that the actual fertility of our soil is decreasing as greater quantities of plant nutrients are being removed than they are being added. More balanced fertilization than we have now in use seems to be needed from the nutritional point of view.

According to Table 7 and Fig. 7, the N contents in straw of the first crop at maturity was lower than that of the second crop, while the K contents was higher. It may be inferred that further N dressing is required in the first crop due to low N contents in straw, while more K is needed in the second crop due to too low K contents in straw. If this is true, although the result was derived from average of only five trials, rice might respond to N fertilizer more effectively for the first crop while K for the second crop. S. C. Chang et al[5] also reported this fact showing this tendency of fertilizer requirements of rice in two crops from the results of the vast number of fertilizer experiments. They[6] carried out forty one N, P, K fertilizer experiments all over the island from 1949 to 1950, reported the following facts as the different response of rice to N, P, K fertilizers in the two crops. % increase in the grain yield due to each N, P and K fertilizer were N 80%, P 5%, K 4% respectively in the first crop and N 35%, P 1%, K 9% in the

second crop. T. Torii[7] stated that high response of rice to K is due to high temperatures resulting in the vigorous vegetative growth of rice in the second crop.

The N and P contents in straw are decreasing from tillering stage to harvesting but the K contents increased again at the later growing stage as mentioned above. Easy dissolution of K out of straw is often lead to under-estimate of K absorption. Therefore the time of sampling in connection with growing stages of rice is very important if the straw composition is used as a guide to judgement on nutritional status.

General speaking, the plants absorb more nutrients and produce higher yield

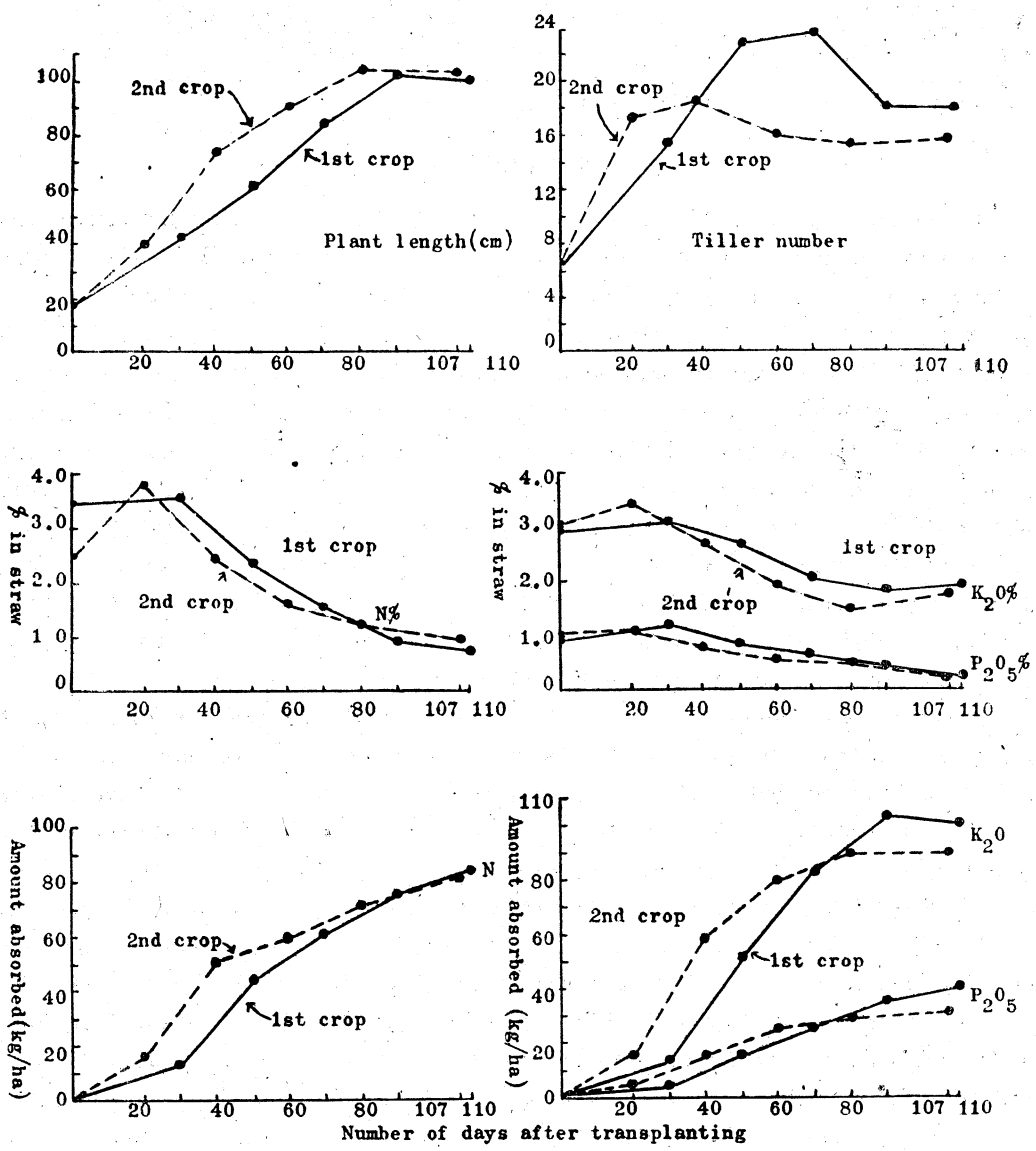

Fig. 7. Comparison of the growth and nutritional status of plants between two crops

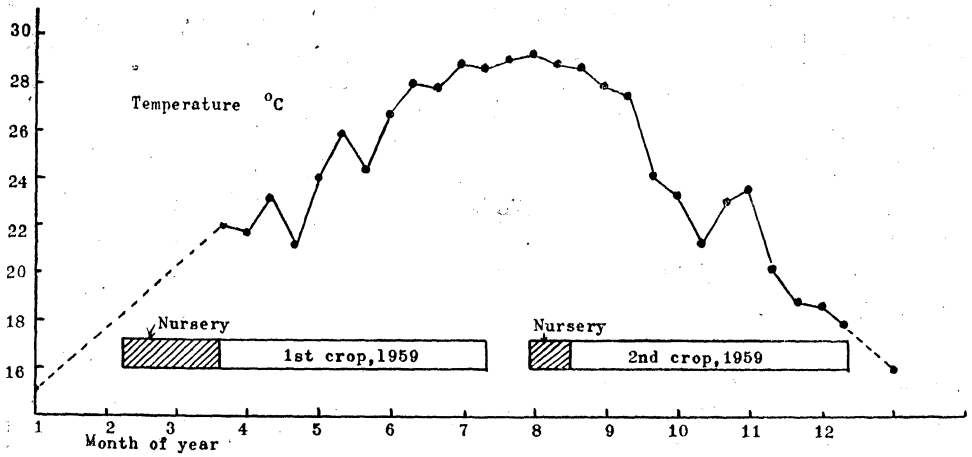

Fig. 8. Average temperatures during rice growth in the two crops in Taipei paddy field (1959)

in the first crop than the second crop. Less tiller number, lower grain yield, grain/straw ratio, and rate of nutrient translocation from straw to grain are found in the second crop. This probably is partly due to different mode of temperatures at critical periods in the two crops, although there are other facters such as disease, day length or soil properties that contribute to this difference. Concerning the effect of the mode of temperatures, Y. Ishizuka and A. Tanaka[8] pointed out that the climatic condition at transplanting in Japan has important meaning with respect to the growth process of rice plants thereafter. In this study they showed that in the warm area, the south of Japan, the plants can revive easily from damage by transplanting and absorb their nutrients vigorously at early stage of growth, but they suffer from shortage of nutrients at later stage of growth. The grain/straw ratio increase from the warm area of south to the cold area of north. The local variation of the N, P, K contents in grain are very small while the contents of these elements in straw are high in the north and low in the south.

It is expected the elucidation of special features of rice nutrition in the two crops might bring about the more reasonable fertilization for getting higher yield, so we are going to continue the experiment along this line.

SUMMARY

Field investigation has been made by using Japonica rice varieties as test crop for the purpose of elucidating the special features of rice nutrition and its growth status between the two crop seasons. Two localities, Yuanlin and Taipei paddy fields in 1959 and three localities, Yuanlin, Taoyuan and Shanchung paddy fields in 1961 were investigated. The results obtained are briefly as follows.

Less tiller number, lower grain yield, grain/straw ratio and rate of nutrient translocation from straw to grain were found in the second crop than in the first crop. The grain/straw ratio observed in the first crop was 104/100 and that in the

second crop was 78/100. The plants grown in the second crop showed vigorous growth with taller culm length at the early stage of vegetative growth but became poor growth and less yield at the later stage of reproductive growth.

The average amounts of three elements, N–P_2O_5–K_2O, absorbed by the plants in the first crop was 84–41–101 Kg/ha, and that in the second crop was 81–32–90 Kg/ha.

The N, P, K contents in straw were usually being increased form transplanting to the tillering stage, then decreased gradually till harvesting, excepting the K contents increased again at the ripening stage, having two peaks at the time of tillering and havresting. It was found at harvesting that the N contents in straw was lower and the K contents was higher in the first crop than in the second crop.

The discussion on the difference of nutritional status between the two crop based on the results obtained from this study has also been given.

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臺灣水稻之養分吸收之研究(第四報)

第一期作與第二期作之水稻營養之比較研究

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摘 要

繼前報以玻璃室試驗調查溫度對水稻養分吸收和生育性狀之影響後本試驗於水田調查蓬萊種水稻在第一期作及第二期作之生理營養特性及生育性狀供爲將來肥培管理之參考。民國四十八年於員林、臺北兩處，民國五十年於員林、桃園、三重三處進行試驗，由其結果可得如下之結論。

第二期作水稻插秧後在營養生長初期雖然生育甚爲旺盛，但至生殖生長期生育較差，產量少。一般而言，第一期作水稻較第二期作者，分蘗多，谷產量多，谷/藁比率高，養分吸收量多，養分之轉移率也高。其各地收穫物之平均結果如下表。

兩期作水稻之生育及營養性狀之比較

生育性狀	第一期作	第二期作	營養性狀	第一期作	第二期作
生育日數	110	107	於谷養分含有率 氮 N	1.16	1.28
草高(公分)	100	103	於谷養分含有率 磷 P_2O_5	0.68	0.64
分蘗數	16.8	15.3	於谷養分含有率 鉀 K_2O	0.35	0.38
谷產量(公斤/公頃)	4,496	3,322	於藁養分含有率 氮 N	0.75	0.91
藁產量(公斤/公頃)	4,305	4,251	於藁養分含有率 磷 P_2O_5	0.24	0.25
谷/藁比率	104/100	78/100	於藁養分含有率 鉀 K_2O	1.99	1.82
養分轉移率(由藁至谷) 氮 N	63	50	養分總吸收量(公斤/公頃) 氮 N	84.0	81.0
養分轉移率(由藁至谷) 磷 P_2O_5	74	64	養分總吸收量(公斤/公頃) 磷 P_2O_5	40.6	31.5
養分轉移率(由藁至谷) 鉀 K_2O	15	14	養分總吸收量(公斤/公頃) 鉀 K_2O	101.3	89.5

就稻藁三要素含有率之變化狀態觀之插秧後各要素之含有率大概增高，第一期作插秧後約於30天，第二期作約於20天達到最高，然後開始逐漸減低直至收穫期。但鉀含有率於成熟期再變爲增高，因各要素中於成熟期由藁部至穗部之轉移率，以鉀素爲最低而殘留於藁部。收穫期藁之氮含有率在第一期作較爲低，但鉀含有率在第二期作較爲低。此營養及生育特性之不同似大部份由兩期作之不同氣候之影響所致。

就收穫物三要素之分佈狀態觀之，氮大部份聚積於谷及葉磷多半以上聚積於谷，而鉀則聚積於莖部最多，葉次之，谷甚少。水稻三要素吸收量，N-P_2O_5-K_2O，每期作平均爲 82-36-95 公斤/公頃，如以 N 爲 100 時，$N:P_2O_5:K_2O$ 之比率爲 100:44:116，由此可知水稻由土壤吸收相當多之鉀素。

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